

## EARLY PERMIAN INADUNATE CRINOIDS FROM THAILAND

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Eight species of Early Permian inadunate crinoids are described from Ko Muk, Ko Phi Phi, and Ko Yao Noi, islands off southern Thailand. These are the first Palaeozoic crinoids described from Thailand and support an Early Permian age for the Phuket Group and Rat Buri Limestone. New species described are *Kallimorphocrinus thaiensis*, *Apographocrinus komukensis*, and *Contocrinus andamanensis*; five species are left in open nomenclature. □ Permian, crinoids, inadunate, Thailand.

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Permian rocks are widespread in Thailand (Waterhouse & Piyasin, 1970, fig. 1; Lumjuan & Lovacharasupaporn, 1984). Since 1960 systematic studies, including stratigraphic interpretations have concentrated on brachiopods (Yanagida, 1984), fusulinids (Toriyama, 1984; Ingavat, 1985), and bryozoans (Sakagami, 1984). This paper is the first to describe Permian crinoids from Thailand.

### LOCATION AND STRATIGRAPHY

Crinoids were derived from five localities on the islands of Ko Muk, Ko Phi Phi, and Ko Yao Noi northwest of Kan Tang in the Andaman Sea off southern Thailand. Maps of the islands showing general position of fossil localities are as follows: 1, upper Phuket Group, SW side of Ko Muk, with stratigraphic sections (Waterhouse, 1982, figs 2b,3,4); 2, upper part of Phuket Group and 3, basal part of Rat Buri Limestone, Ko Phi Phi, indicated on measured section of Tong Lang Bay (Waterhouse, 1982, fig. 2a); 4, Rat Buri Limestone, Ko Muk, U.S. National Museum locality 9271 (Grant, 1976, fig. 7); and 5, Rat Buri Limestone, Ko Yao Noi, (Waterhouse et al., 1981), fig. 4. An unsuccessful attempt was made to locate the calyx reported by Waterhouse (1982, p. 339), from the Phuket Group on Ko Phi Phi for inclusion in this study.

In southern Thailand Phuket Group brachiopods are considered Sakmarian (Waterhouse et al., 1981; Waterhouse, 1982). The Rat Buri Lst has been considered Artinskian (Sakagami, 1970; Yanagida, 1970; Grant, 1976), late Early Permian (Yanagida, 1984), Kazanian (Waterhouse & Piyasin, 1970) or Kungurian (Waterhouse, 1981).

The Rat Buri Limestone has been applied somewhat indiscriminately to Permian lime-

stones throughout Thailand (Grant, 1976). Diversity of carbonate microfacies within the Rat Buri Limestone is reflected in the reports of many beds with restricted faunas, i.e., fusulinids with rare or no brachiopods or abundant brachiopods and bryozoans with no fusulinids (Grant, 1976). Fusulinids are virtually unknown in the Rat Buri Limestone in peninsular Thailand (Toriyama, 1984, fig. 1), but in central and northern Thailand fusulinids range from Sakmarian to Dorashamian (Ingavat, 1985). A Sakmarian ammonoid fauna occurs in the basal Rat Buri Limestone in central Thailand (Glenister et al., 1990). Waterhouse (1981) correlated the Rat Buri Limestone of southern Thailand with the Bitauai Beds of Timor. However, the Bitauai Beds are considered Artinskian based on ammonoids (Glenister & Furnish, 1987).

Considerable work remains in determining stratigraphic relationships of the Rat Buri Limestone throughout Thailand. However, sufficient palaeontological information is available to evaluate the age of the unit at most localities. Based on fusulinids and ammonoids the base of the Rat Buri Limestone in central and northern Thailand is Sakmarian or Artinskian. In peninsular Thailand we consider the Rat Buri Limestone to be of Artinskian age based on data of Sakagami (1984) and Yanagida (1984) and correlation of the brachiopod faunas with the Timorese Bitauai fauna (Grant, 1976; Waterhouse, 1981).

Clastic sediments of the Phuket Group have been referred to as cool water deposits equivalent to glaciomarine deposits of Gondwanaland (Waterhouse, 1982 among others). Altermann (1986) considered these deposits to represent deposition on a continental margin lacking sufficient evidence to interpret them as glaciomarine. Brachiopods from a carbonate band within the pebbly

mudstones in the upper part of the Phuket Group were interpreted by Waterhouse (1982) as mostly cool temperate genera. Brachiopods from the Rat Buri Limestone were interpreted (Grant, 1976) as tropical with marine connection to cooler water. Waterhouse (1982) considered the brachiopod faunas of the Rat Buri Limestone to have a stronger cool temperate composition.

#### FAUNAL SIGNIFICANCE

All crinoids reported are allagecrinid or advanced poteriocrinid cladids. The allagecrinid *Kallimorphocrinus* occurs in the Carboniferous and Permian in North America, the Carboniferous of Europe and Permian of Timor and Russia (Bassler & Moodey, 1943; Webster, 1973, 1977, 1986, 1988). *K. thaiensis* and *K.?* sp.nov. from the Phuket Group are related to Permian *Kallimorphocrinus* and *Wrightocrinus* from Timor.

The dorsal cup from the Phuket Group, assigned to *Cymbiocrinus* is the second report of the genus from the Permian and outside North America. *Cymbiocrinids* are considered the ancestral stock of the calceolispongiids, a Tethyan family restricted to the Permian of Australia, Timor and India (Moore & Strimple in Moore & Teichert, 1978). The bulbous basals of *Cymbiocrinus* are considered a continuation of the cymbiocrinid lineage in parallel with the calceolispongiids which had branched off earlier.

The other advanced poteriocrinid from the Rat Buri Limestone are small specimens, perhaps not fully mature. They belong to genera that are relatively small but typically larger than these specimens. *Apographiocrinus* is known from the Upper Carboniferous and Lower Permian of North America and the Permian of Russia, Timor and Western Australia (Bassler & Moodey, 1943; Webster, 1973, 1977, 1986, 1988). *A. komukensis* is most similar to *A. pumilus* of the Early Permian Callytharra Formation of Western Australia (Webster, 1987) and Permian Basleo Beds of Timor (Wanner, 1916). The partial crown questionably assigned to *Apographiocrinus* has a more elongate cup than is typical in the genus. This may reflect immaturity as height:width ratio of the cup may decrease with growth as in other inadunates (Pabian & Strimple, 1985).

*Contocrinus* is known only from the Late Carboniferous and Early Permian of North America (Webster, 1973, 1977). The advanced condition of the anal interarea in *Contocrinus andamanensis* sp.nov. suggests a Permian age. The partial crown questionably assigned to the Clathrocrini-

dae has arm structure similar to the Late Carboniferous *Clathrocrinus* known only from North America (Webster, 1977, 1986). Cup features suggest advanced morphology common in Late Carboniferous or Permian poteriocrinids.

None of the three poteriocrinid genera from the Rat Buri Limestone are restricted to the Permian; they occur in the Late Carboniferous and Permian or Late Carboniferous only. The lack of strong ornament on the cladids may indicate they are farther offshore or deeper water forms (Pabian & Strimple, 1985). Preservation of crowns with proximal columnals attached implies little if any postmortem transport.

Crinoid ossicles are common elements with brachiopods and bryozoans in shallow shelf carbonates and marls in the late Palaeozoic (Lane & Webster, 1980; Pabian et al., 1989). All Thai crinoids discussed were associated with brachiopods and bryozoans. However, crinoids were sparse in residues from the Phuket Group and the Rat Buri Limestone. Some samples were totally lacking in crinoidal debris. This is considered a reflection of some paleoecologic control, perhaps water temperature.

#### SYSTEMATIC PALAEOONTOLOGY

Morphologic terminology follows Moore & Teichert (1978). Specimens are deposited in the: United States Nation Museum (USNM), University of Tasmania (UT) and University of Queensland (UQ).

- Class CRINOIDEA Miller 1821
- Subclass INADUNATA Wachsmuth & Springer, 1885
- Order DISPARIDA Moore & Laudon, 1943
- Superfamily ALLAGECRINOIDEA Carpenter & Etheridge, 1881
- Family ALLAGECRINIDAE Carpenter & Etheridge, 1881

#### *Kallimorphocrinus* Weller, 1930

##### TYPE SPECIES

*K. astrus typicum* (= *K. astrus astrus*) Weller, 1930 from the Late Carboniferous Perth Limestone, Indiana; by original designation.

#### *Kallimorphocrinus thaiensis* sp.nov. (Fig. 1A-F)

##### ETYMOLOGY.

From Thailand.

## MATERIAL AND LOCALITY

Holotype UQF79668; paratypes UQF79669, 79670, silica replacements of thecae from a Permian unit, probably the Rat Buri Limestone, on Ko Muk.

## DIAGNOSIS

Radials gently rounded, tumid. Thecal outline rounded pentalobate in oral view.

## DESCRIPTION

Theca bowl-shaped, higher than wide, greatest width just above midheight, incurved to radial summit, rounded pentalobate in oral view. Dorsal cup tumid, flat-based, bowl-shaped, finely pitted.

BB 2 or 3, sutures obscured by silicification, forming lower 1/3 of cup height in lateral view, RR 5, approximately twice as long as wide, narrower at base than radial summit, convex horizontally and longitudinally, prominently rounded tumid at 3/4 length, subequal in size, becoming wider with increasing facets. Radial summit horizontal, 1-3 facets per radial. Facets with well developed transverse ridge; muscle field in moderately deep depression sloping inward to ambulacral canal. Anal facet small, equidimensional, on left shoulder of C radial. OO 5, well elevated, slightly inset on radial summit, forming a quarter thecal height, dart-shaped, shaft sides vertical, oral surface with two faint ridges parallel to sides, extending nearly to centre of circlelet. Posterior oral largest, separating BC and DE orals, probably bearing hydropore or madreporite. Proximal columnal circular transversely, much wider than high.

## MEASUREMENTS OF HOLOTYPE (mm)

Thecal height, 3.1; maximum width, 2.6; height BB circlelet, 0.9; radial length 1.6, width, 1.4; height OO circlelet 0.7; proximal columnal diameter 1.3, height 0.2.

## REMARKS

The description is based on the holotype, a specimen with 9 arm facets, 2 on A and B radials, 1 each on the C and E radials, and 3 on the D radial, and the paratype, a partial theca lacking the basal circlelet and adjacent basal ends of the radials. The paratype bears one arm facet on each radial and the A facet appears to have the initial stage of a second facet developing on the right side. Both specimens fit the generic definition as revised by Lane & Sevastopulo, 1982.

*Kallimorphocrinus thaiensis* is distinguished by the rounded protuberance of the radials being greatest at 1/2 thecal height. The Early Carbonif-

erous, *K. astrus* and *K. piasaensis*, also have their greatest protuberance below the radial facet but their protuberance is much sharper making their thecae more pointed pentalobate in lateral and oral views. The only other Permian species, *K. eaglei* (Strimple, 1966), from Oklahoma and Nevada has exceedingly bulbous radials and much lower basals.

An aberrant specimen with four orals is assigned to *K. thaiensis*. It has no arm facet on the A radial and the EA and AB orals are fused. There are two arm facets each on the B and D radials, and one each on the C and E radials. The BC oral is not preserved but facets for its articulation are visible on the specimen. The A radial is narrower than the other radials and narrowest at the top where it abuts the abnormal oral. The orals are larger and higher than those of the types.

Silicification has obliterated details of ornament and oral and radial facets. All are judged to be immature as they retain the oral plates.

***Kallimorphocrinus?* sp.**  
(Fig. 1G-J)

## MATERIAL AND LOCALITY.

UQF79666, 79667, silica replacements of thecae associated with *K. thaiensis* from the Early Permian Rat Buri Limestone, Ko Muk.

## DESCRIPTION.

Theca truncate bowl-shaped, higher than wide in immature forms, wider than high in more mature forms, walls gently flared outward nearly to radial summit, widest just below radial summit. Dorsal cup rounded pentalobate in oral view, walls smooth.

BB circlelet fused, low, forming lower 1/4 of cup in immature forms, shallowly concave on circular facet for stem attachment, flaring upward from edge of stem facet. RR 5, longer than wide, narrowest at base, flaring gently outward nearly to facet, moderately convex transversely; convexity increasing distal of facet, becoming wider with increasing number of facets. Radial facets with transverse ridges, outer ligament pits and muscle fields on deep pit sloping inward, with one or more facets per radial in adults. Anal notch small, on left shoulder of C radial.

OO 5, forming rounded dome; individually approximately dart-shaped, widest medially; walls straight, vertical; oral surface with shallow central depression bordered by narrow U-shaped rim closed on aboral end.

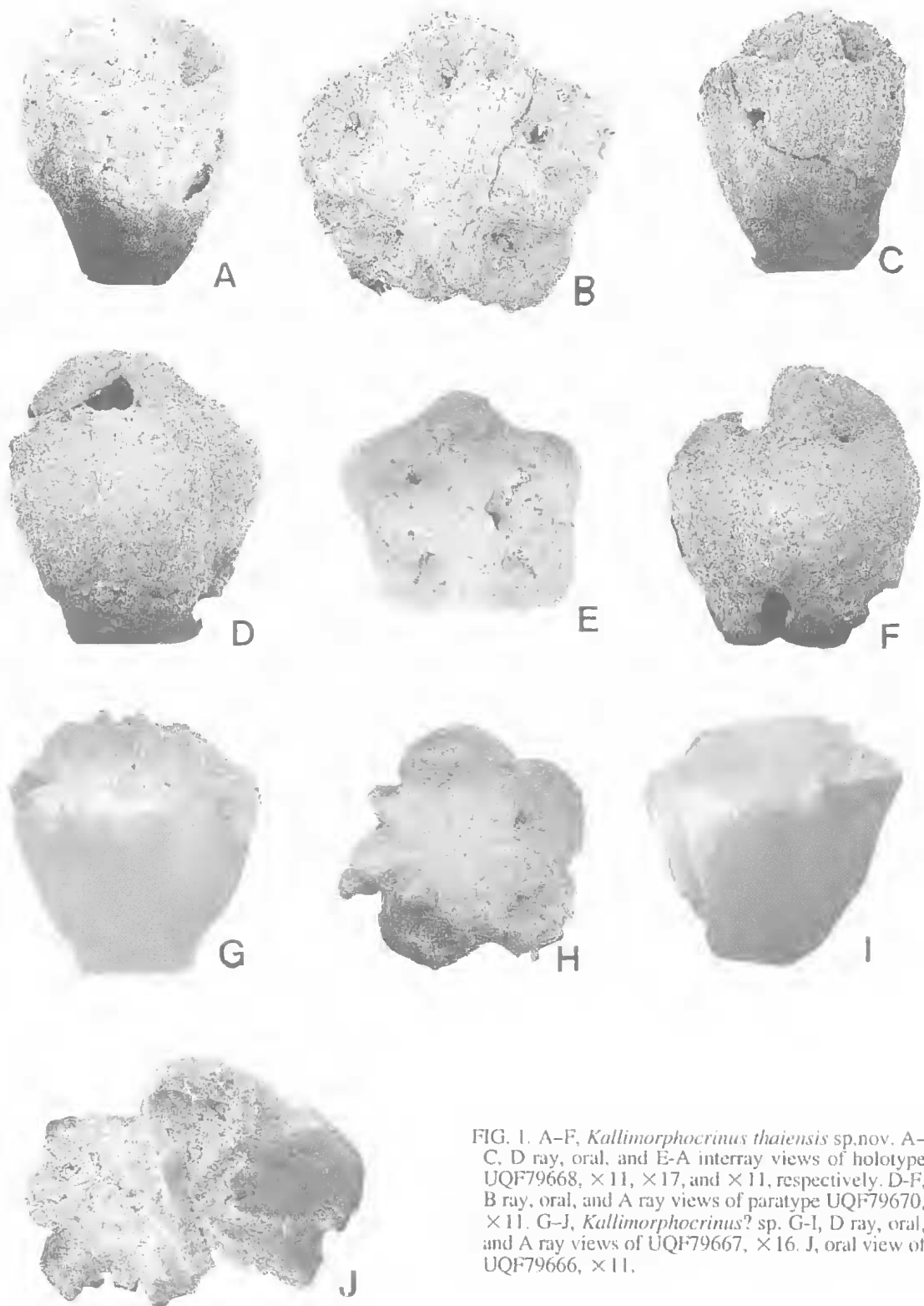


FIG. 1. A-F, *Kallimorphocrinus thaiensis* sp.nov. A-C, D ray, oral, and E-A interray views of holotype UQF79668,  $\times 11$ ,  $\times 17$ , and  $\times 11$ , respectively. D-F, B ray, oral, and A ray views of paratype UQF79670,  $\times 11$ . G-J, *Kallimorphocrinus?* sp. G-I, D ray, oral, and A ray views of UQF79667,  $\times 16$ . J, oral view of UQF79666,  $\times 11$ .

## MEASUREMENTS (mm)

	U Q F 79666	U Q F 79667
Height of theca	2.0	3.4*
Max. width of theca and cup	2.0	4.5
Height of dorsal cup	1.7	3.3*
Height of RR	1.3 (A)	3.1 (D)
Width of RR	1.0 (A)	1.8 (D)
Height of BB circlet	0.5	—
Height of OO circlet	0.3	0.1
Diameter of the stem facet	0.8	—

\* estimated

## REMARKS

The description is based on an immature five-armed theca lacking a small part of the outer wall of the C radial and a larger partial theca lacking virtually all the A radial, most of the B radial, and subjacent part of the basal circlet. This second specimen has one arm facet on the E radial, two on the D radial, one, two or three on the C radial, and at least one on the B radial. Silicification has obliterated some details of the oral plates and radial facet.

Doubts about generic assignment stem from two features. The anal notch could be a result of silicification on the smaller specimen and actually be an arm facet on the larger specimen. Secondly the radials closely resemble those of *Wrightocrinus jakovlevi*, to which this species could be related.

*Kallimorphocrinus*, as redefined by Lane & Sevastopulo, 1982, has up to 14 arms with only one arm in each of the C and E rays, an anal series, and loss of the orals in adults. Moore (1940) proposed *Wrightocrinus* as an allagecrinid with or without an anal series distinguished by the single arm on each of the B and E radials in adults. He designated *Allagecrinus jakovlevi* Wanner, 1929 as type. Wanner (1929) reported 125 specimens of *A. jakovlevi* and analysed 71 specimens as having 1 arm in each of the B and E rays with one exception having 2 arms in the B ray. Marez-Oyens (1940) reported an additional 199 specimens of *A. jakovlevi* with only 12 specimens having 2 (10 specimens), 3 (one specimen), or 4 (one specimen) arm facets on the B radial. It is possible that most of these exceptions are incorrectly identified and are actually kallimorphocrinids or other allagecrinids as they only have one arm facet on the C and E radials with one exception with two on the C radial.

The number of arms in each ray in adult microcrinoids may be generically diagnostic of some

allagecrinids (Moore, 1940; Moore & Strimple in Moore & Teichert, 1978). For example, *Wrightocrinus* normally has only one arm in each of the B and E rays, whereas *Kallimorphocrinus* has one arm in each of the C and E rays, and both genera have more than one arm in each of the other rays. The radials of the two specimens assigned to *Kallimorphocrinus?* sp. are very similar in shape to those of *Wrightocrinus jakovlevi* (Wanner, 1929) a Permian form from Timor. If there were no question about the number of facets on the B and C radials in the larger specimen we would assign the specimens unquestioned to either *Wrightocrinus* or *Kallimorphocrinus*.

The only other species, previously assigned to *Wrightocrinus* is *Allagecrinus bplex* Wright, 1932 (designated genotype of *Thaminocrinus* Strimple & Watkins, 1969), a Viscean form from Scotland with an anal series. Moore (1940) considered the lack of an anal series in the Permian species to be an advanced evolutionary feature for the genus. Neither Wanner (1929) nor Marez-Oyens (1940) recognised specimens of *A. jakovlevi* with less than 9 arms, however, they both recognised specimens of *A. quinquebrachiatus* Wanner, 1929, a form with 5 arms and no anal series and a cup shape, radial form and oral configuration like that of *A. jakovlevi* but approximately one half the size. Strimple (1966) proposed *Metallagecrinus* designating *A. quinquebrachiatus* as type. If *A. quinquebrachiatus* is the immature form of *W. jakovlevi*, as we believe, then *Metallagecrinus* is a junior synonym of *Wrightocrinus*.

Strimple (1966) assigned an additional 11 species to *Metallagecrinus* because they all lacked an anal series, retained the oral circlet, and had one arm per ray. Strimple & Sevastopulo (1982) reconsidered these assignments and suggested *M. multibracliatus* (Yakovlev, 1927), *M. dux* (Wanner, 1930) and *M. inflatus* (Wanner, 1929) should be excluded because they differ in several respects from the type. We agree with this assessment and would transfer all other species [*M. acutus* (Wanner, 1929), *M. excavatus* (Wanner, 1929), *M. indoaustralicus* (Wanner, 1916), *M. quinquelobus* (Wanner, 1929), *M. procerus* (Wanner, 1929), *M. ornatus* (Wanner, 1929), *M. uralensis* (Yakovlev, 1927) and *M. uralensis nodocarinatus* (Yakovlev, 1927) as well as *M. palermoensis* Strimple & Sevastopulo, 1982 to *Litocrinus* Lane & Sevastopulo, 1982.

Order CLADIDA Moore & Landon, 1943  
 Suborder POTERIOCRININA Jaekel, 1918  
 Superfamily SCYTALOCRINOIDEA  
 Moore & Laudon, 1943

### Family and Genus uncertain

#### MATERIAL

One partly silicified dorsal cup, UQF79665, from acid residue of loose boulder of Rat Buri Limestone from the southeast part of small bay; Ban Hat Yao, on the northern end of Ko Yao Noi, southern Thailand.

#### REMARKS

This cup is 5.8mm wide, 3.4mm high, cone-shaped, with truncated base, steeply outflared plenary radial facets, with a single small anal in a notch shared by the C and D radials. Infrabasals small, slightly upflared. Ornament destroyed by silicification if present; stem facet round. Anal sac and arms unknown.

Advanced features present on the cup are the plenary facets and anal plate nearly out of the cup. A primitive feature retained is the conical shape. The specimen is questionably assigned to the scytalocrinoids because of its shape, radial facets, and number and position of the anal.

The specimen is not well enough preserved to be designated a type or effectively illustrated. It is mentioned because it adds to the generic diversity in the Permian of Thailand.

Superfamily DECAOCRINOIDEA Bather,  
1890

Family CLATHROCRINIDAE Strimple &  
Moore, 1971

*Clathrocrinid* gen. et sp. nov.  
(Fig. 2 O,P)

#### MATERIAL AND LOCALITY

One crown, USNM450329, from acid residue of the Rat Buri Limestone, locality USNM9271, northwest side of Ko Muk, NW of Kan Tang (Grant, 1976).

#### DESCRIPTION

Crown small, elongate, subcylindrical, with arm girdle at top of primibrachials, 10 arms slender with offset brachials in zig-zag pattern. Cup crushed, medium bowl; walls outflaring, gently convex; base invaginated; sutures flush; radial notches obvious; ornament lacking. IBB not visible in lateral view. BB 5, slightly longer than wide, gently convex transversely, strongly convex proximally, gently convex distally, proximal

end forming base of cup. RR 5, wider than long, gently convex transversely and longitudinally; facet angustary, lacking prong-like internal extensions on lateral ends of upper surface; small gape with primibrachials at facet. Single anal relatively large, longer than wide, with proximal third below radial summit, sitting on top of truncated laterally symmetrical CD basal, with distal two-thirds incurved above radial summit, adjoined distally by two tube plates. IBrr one per ray, axillary, longer than wide, widest at base, laterally constricted in central three-fourths, strongly convex transversely, gently concave longitudinally, bearing prominent slightly upward directed spine at distal end. IIBrr elongate, cuncate, twice as long as wide proximally, three times longer than wide distally, widest on distal end, strongly convex transversely, longitudinally straight becoming concave distally, bearing prominent slightly upward directed spine on distal end. Pinnules large, could be considered ramules, elongate, strongly convex transversely, alternate on sides of arm, one per brachial on distal end of brachial.

#### MEASUREMENTS (mm)

Crown length 31.6 (incomplete), width 10.6; cup height 5.8, width 4.2 (estimated); BC basal length 3.6, width 3.5; E radial length 4.2, width 5.8; anal length 3.8, width 3.2; IBr1 length 4.1, width 3.8; IIBr1 length 5.8, width 2.8; IIBr5 length 4.6, width 1.7.

#### REMARKS

No name is given to this distinctive specimen because the cup is crushed. Infrabasals are not preserved; the BD, CD and DE basals and C, D and E radials are preserved.

Classification is based on arm structure. The angustary radial facets, elongate brachials, pinnules that are essentially ramules, zig-zag pattern of the brachials, and spine on the distal end of the brachials all have affinity with the Clathrocrinidae. Unlike *Clathrocrinus* only one anal occurs within the radial summit, indicating an advanced condition, and the zig-zag pattern of the brachials is not as widely spreading. We consider this specimen to have evolved from a clathrocrinid ancestor in Early Permian times. Range of the family is extended into the Permian and its distribution, previously confined to North America, is extended to Southeast Asia.

Superfamily ERISOCRINOIDEA Wachsmuth & Springer, 1886  
 Family GRAPHIOCRINIDAE Wachsmuth & Springer, 1886

**Contocrinus Knapp, 1969**

**TYPE SPECIES**

*Graphiocrinus stantonensis* Strimple, 1939  
 from the Upper Carboniferous Wann Formation, Oklahoma, by original designation.

***Contocrinus andamanensis* sp. nov.**  
 (Fig. 2E-H)

**ETYMOLOGY**

For the Andaman Sea.

**MATERIAL**

Holotype USNM450326; paratype USNM450325, Rat Buri Limestone, locality USNM9271, NW side of Ko Muk, Thailand.

**DIAGNOSIS**

Small, with a shallow arm girdle, large elongate posterior basal, and anal distally adjoined by two tube plates.

**DESCRIPTION**

Crown elongate, slender, with slight arm girdle at base of secundibrachials, 10(?) arms. Cup medium bowl-shaped, widest slightly below radial summit, with moderate basal invagination; sutures between basals slightly impressed, sutures between radials deeply impressed; apical pits at top of basals and base of radials; granular to vermiform ornamentation. IBB 5, small, slender, strongly tapering, downflaring, not visible in lateral view, covered by proximal columnal. BB 5, outflaring, strongly convex longitudinally and transversely, slightly wider than long, proximally forming base of cup; posterior basal larger, more elongate. RR 5, slightly outflaring, wider than long, strongly tumid. Radial facets plenary, sloping outward, with moderate gape, outer ligament area wide, with pit; transverse ridge full width of facet. Anal slightly longer than wide, proximally adjoining truncated transversely symmetrical CD basal, distal end projecting slightly above radial summit, followed by two tube plates. IBrr one per ray, axillary, medially constricted, strongly convex transversely, gently concave longitudinally, slightly wider proximally than distally. IIBrr slightly longer than wide, slightly cuneate, strongly convex transversely, weakly convex

longitudinally; sutures slightly impressed. Proximal columnals heteromorphic, transversely round, latus convex, symplexy articulation; lumen not preserved.

**MEASUREMENTS (mm).**

	U S N M 450325	U S N M 450326
Crown length (incomplete)	14.0	15.0
Cup height	2.0	3.4
Cup width (through A-CD)	5.9	7.3
Diameter IBB circlet		0.9
AB basal length	1.8	2.4
AB basal width	1.9	2.8
A radial length	1.7	2.4
A radial width	2.8	3.2
IIBR1 length	2.9	4.5
IIBR2 width	2.8	3.7
IIBR1 length	1.9	2.3
IIBR1 width	1.7	2.2
IIBR5 length	1.2	1.4
IIBR5 width	1.0	1.9
Anal length	1.8	1.6
Anal width	1.4	1.5
Diameter proximal columnal	1.5	1.3

**REMARKS**

There are probably 10 arms. The D and E rays are not preserved on the paratype and the A, B and E rays are not preserved on the holotype. All preserved rays bear 2 arms. Pinnules are not preserved on either specimen but articular facets for the pinnules are poorly preserved on the distal outer corner of some of the distal secundibrachials. Noditaxis patterns are not well developed on the proximal pluricolumnal segment, but variable thicknesses of the 6 columnals suggest a simple heteromorphic Type 1 pattern of Webster (1974). Ornamentation is more finely granular on the holotype than the paratype.

These specimens are transitional between the graphiocrinids and apographiocrinids. The arm girdle and two tube plates adjoining the anal plate relate the specimens to the apographiocrinids. However, plenary radial facets and lack of prong-like extensions on the radials between the facets show affinity to the graphiocrinids. We consider the plenary radial facets to be of greater importance in classification than the number of tube plates adjoining the anal plate.

*Contocrinus andamanensis* has less tumid cup plates and a longer posterior basal than the most similar *C. scopulus* (Lane & Webster, 1966). Both

species are smaller than Pennsylvanian species; because both are based on few specimens, it is not known if they are mature or not.

This is the first report of *Contocrinus* outside North America, although graphiocrinids, i.e. *Permiocrinus* Wanner, 1949 is known from Timor. Most Timor species initially assigned or transferred to *Graphiocrinus* by Wanner, 1949, have been assigned to other families of advanced periocrinids (Webster, 1987, among others).

Superfamily APOGRAPHIOCRINOIDEA  
Moore & Laudon, 1943

Family APOGRAPHIOCRINIDAE Moore &  
Laudon, 1943

*Apographiocrinus* Moore & Plummer, 1940

TYPE SPECIES

*A. typicalis* Moore & Plummer, 1940 from the Pennsylvanian Plattsburg Limestone, Kansas, U.S.A., by original designation.

*Apographiocrinus komukensis* sp. nov.  
(Fig. 2A-D)

ETYMOLOGY

From the island of Ko Muk.

MATERIAL

Holotype USNM450328 and paratype USNM450327 from acid residues of Rat Buri Lst at locality USNM9271, NW side of Ko Muk.

DIAGNOSIS

High cup, with less tumid plates, ornament variable, finely granular to verniform.

DESCRIPTION

Cup medium bowl-shaped, nearly twice as wide as high; walls gently convex, outflared; base with moderately deep invagination; sutures weakly impressed; apical pits shallow; ornament very fine and granular. IBB 5, small, dart-shaped, downflaring, not visible in lateral view. BB 5, slightly wider than long, gently convex transversely and longitudinally, proximal end forms base of cup and edge of basal invagination. RR 5, wider than long, gently convex longitudinally, strongly convex transversely; facets angustary, sloping outward; internally extending prong-like ridges separating facets; well developed radial notches in lateral view. Anal slightly longer than wide, proximal end adjoins truncated laterally symmetrical CD-basal, distal third extends above

radial summit, facets for two adjoining tube plates distally. IBrr one per ray, slightly longer than wide, constricted medially, transversely convex, longitudinally concave; axillary, isotomous branching. Stem impression round.

MEASUREMENTS (mm)

	U S N M 450328	U S N M 450327
Crown height	4.2	3.0*
Cup width	7.6	6.0
Diameter IBB circle	2.0	1.5
AB basal length	2.5	2.0
AB basal width	2.9	2.4
A radial length	2.4	2.0
A radial width	4.0	3.4
Anal length	2.1	—
Anal width	1.6	—
IBRI length	—	2.9*
IBRI width	—	2.7

\*estimated

REMARKS

The paratype has more tumid cup plates, some verniform ornamentation, more impressed sutures, and a lower, more outflaring bowl configuration than the holotype. Although possibly distinct species we consider them one on available material. Angustary radial facets, prong-like projections between radial facets, and facets for two tube plates distal to the anal relate these forms to *Apographiocrinus*.

Three species of *Apographiocrinus*, *A. pumilus*, *A. quinquelobus*, and *A. rugosus*, although initially assigned to other genera, were reported from Permian strata of Timor by Wanner, 1916. All three species have much coarser ornament, ornament of a different type, or much more tumid basals and radials than *A. komukensis*. Late Carboniferous species of *Apographiocrinus* known from North America have less tumid cup plates, are much larger, and have more outflared cup walls than *A. komukensis*.

*Apographiocrinus?* sp. nov.  
(Fig. 2L-N)

MATERIAL AND LOCALITY

One partial crown, UTGD124566 from the basal part of the Rat Buri Limestone from Ko Phi Phi, an island northwest of Kan Tang, recovered by Clive Burrett. Sample No KP(B).



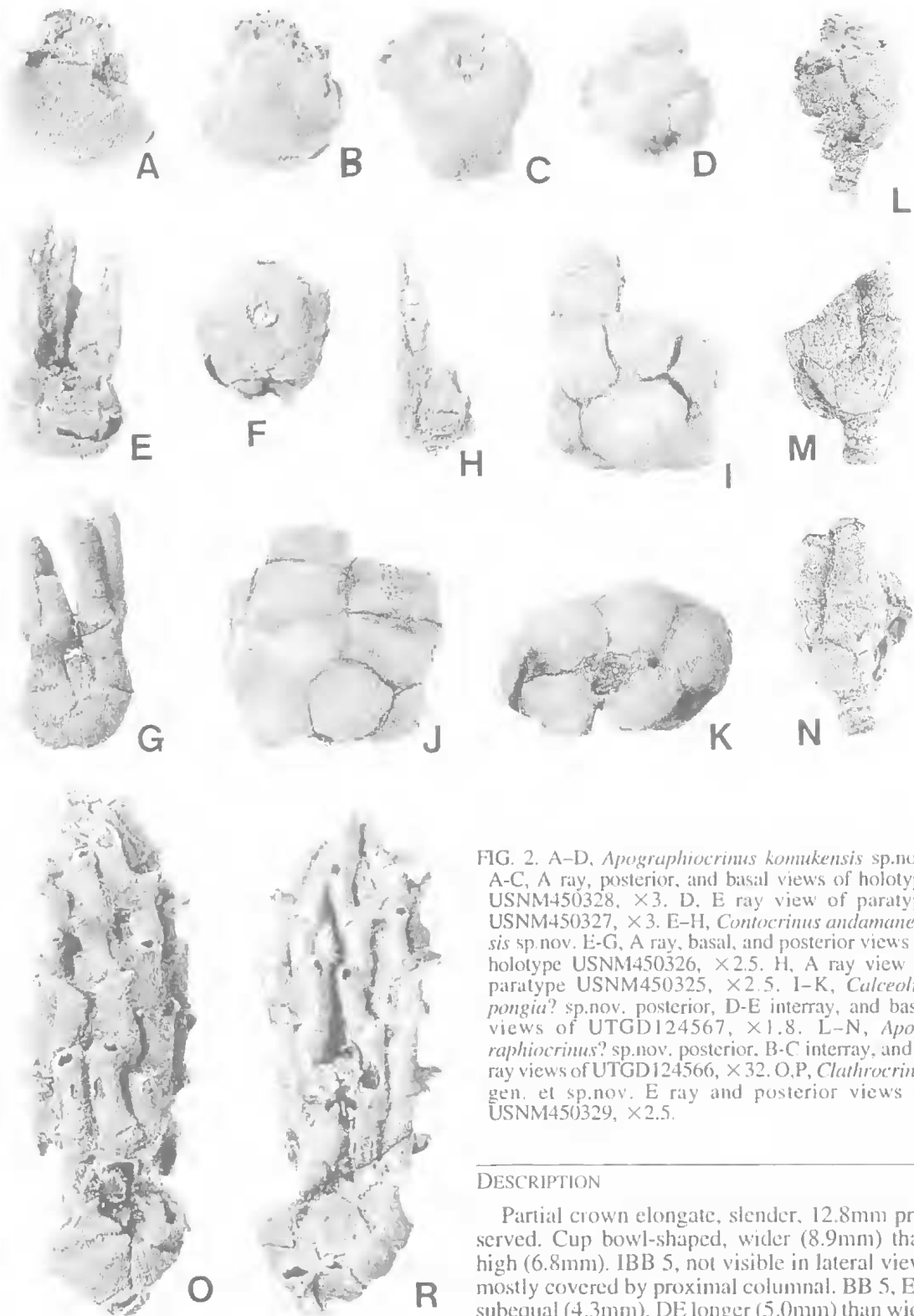


FIG. 2. A-D, *Apographiocrinus komukensis* sp. nov. A-C, A ray, posterior, and basal views of holotype USNM450328,  $\times 3$ . D, E ray view of paratype USNM450327,  $\times 3$ . E-H, *Contocrinus andamanensis* sp. nov. E-G, A ray, basal, and posterior views of holotype USNM450326,  $\times 2.5$ . H, A ray view of paratype USNM450325,  $\times 2.5$ . I-K, *Calceolispongia?* sp. nov. posterior, D-E interray, and basal views of UTGD124567,  $\times 1.8$ . L-N, *Apographiocrinus?* sp. nov. posterior, B-C interray, and A ray views of UTGD124566,  $\times 32$ . O, P, *Clathrocrinid* gen. et sp. nov. E ray and posterior views of USNM450329,  $\times 2.5$ .

DESCRIPTION

Partial crown elongate, slender, 12.8mm preserved. Cup bowl-shaped, wider (8.9mm) than high (6.8mm). IBB 5, not visible in lateral view, mostly covered by proximal columnal. BB 5. EA subequal (4.3mm), DE longer (5.0mm) than wide

(4.8mm), convex proximally forming basal plane, gently convex and subvertical distally. Posterior basal heptagonal, truncated distally for reception of anal. RR 5, A radial wider (4.8mm) than long (3.5mm), moderately convex transversely, gently convex longitudinally, subvertical to slightly incurved distally, lateral sutures impressed. Radial facets peneplenary, sloping gently outward, low lateral prongs extending internally as lateral ridges with adjoining radials. Single anal longer (2.9mm) than wide (2.1mm), gently convex transversely and longitudinally, proximal 3/4 below radial summit, adjoins 2 tube plates distally.

IBr one per ray, axillary, longer (6.5mm) than wide (4.5mm) widest at base, longitudinally convex-concave, transversely convex, constricted below distal facets, unequal in length, ?A ray IBr longest. Proximal columnals heteromorphic, transversely rounded, latus gently convex, lumen ?pentalobate.

#### REMARKS

The specimen is silicified and slightly distorted basally. Parts of B radial and AB through CD basals not preserved. Only A and E IBr complete, C & E IBr partly preserved. The infrabasal circlet is not visible but internal walls of etched basals show two facets for attachment to infrabasals. There were probably 5 small infrabasals down-flared or subhorizontal.

The arms branch isotomously on the E and A primibrachs, suggesting 10 arms if the same branching pattern occurred in all rays.

The specimen is referred to the Apographocrinidae because it has peneplenary radial facets, lateral prongs on the radial facets, and 2 tube plates distal to the single anal. The cup is more elongate than in the rest of the family, indicating a less advanced form than might be expected in a Permian member. Constriction in the distal part of the primibrachs suggests development of an arm girdle. It is left in open nomenclature in hope of future recovery of additional specimens.

#### *Cymbiocrinus?* sp. nov. (Fig. 2I-K)

#### MATERIAL AND LOCALITY

Partial crown, UTGD124567, found by Clive Burrett in the upper Phuket Group on Ko Phi Phi. It occurs in a unit with Early Permian brachiopods considered to indicate a temperate climate (Waterhouse, 1982).

#### DESCRIPTION

Partial crown crushed subparallel to anterior-posterior plane of symmetry. Cup moderate bowl-shaped, with shallow to moderate basal invagination; plates bulbous, not ornamented. IBB not preserved. BB 5, strongly convex in all directions, subequal length (8.4mm) and width (8.1mm), forming basal plane, hexagonal except heptagonal posterior basal truncated for anal plate. RR 5, half again wider (10mm) than long (6.3mm), convex longitudinally and transversely. Radial facets plenary.

Single large anal, essentially below radial summit, gently convex longitudinally and transversely, longer (4.7mm) than wide (4.6mm). IBr 2 in B ray, wider (9.7mm) than long (5.2mm) gently convex longitudinally and transversely, IBr2 axillary. C ray IBr larger, 10.2mm wide, 5.8mm long, non-axillary. Additional brachials and stem not preserved.

#### REMARKS

Specimen replaced by hydrous iron oxides, B radial lost, some loss by solution of plates adjacent to B radial. Radial facets well developed and sloping inward but solution has destroyed details of exposed surfaces. Infrabasals lost, small, probably 5 and down flared or subhorizontal, mostly covered by proximal columnals. Pluricolumnal segments in the matrix block are transversely rounded but not attached to the cup. It is not certain that they were part of the original animal but it seems likely.

The bulbous basals and large radianal suggest relationship with the calceolispongiids. However, branching on the second primibrach is unknown in the calceolispongiids but is typical of *Cymbiocrinus* which has a single anal. We consider the calceolispongiids to have evolved from the Cymbiocrinids adapting to cooler water elastic dominated environments of the Permian of Australia. The specimen is left in open nomenclature in hope of a future discovery of a better specimen to serve as holotype.

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